CHAPTER 16

# The Technology

## Getting Ready...

- Why are seat belts and air bags so effective in preventing injuries and fatalities?
- How is the seat belt designed?
- How can air bags be dangerous?
- Where and how should children sit in a vehicle, and why?

The 2000 Buick LeSabre is said to be one of the safest cars ever built. How does its design differ from that of the 1959 Buick LeSabre?

## Science Log

Identify the safety features of a vehicle of your choice. Check the owner's manual to see what safety features are listed. Look for any recent news stories about problems with this vehicle. Do any features need to be changed because they are dangerous?

In the previous three chapters, you learned about how the laws of physics affect traffic safety and the motion of cars during collisions. This chapter is about using tests, like crash tests, to build safer cars.

Cars are safer today than they were even 10 years ago because safety engineers use what they learn from investigations with crash test dummies to build safer vehicles. Such work starts with research.

Researchers examine accident reports and identify safety needs. For example, research might show that passengers are slamming into dashboards on impact. Safety engineers use crash tests to help them design a feature to prevent such problems.

Every part of the car is engineered with safety in mind.

In this chapter you will learn what safety features keep you safe. You will sit in the chair of a safety engineer as you consider how to improve these safety features.

# of Safety

## What You Will Learn

In this chapter you will learn:

- how safety features use the laws of physics to protect you from harm during collisions
- about advances in seat belt and air bag design
- how seat belts and air bags are designed with laws of motion in mind
- about new advances in technology that could lead to even safer vehicles in the future
- how child seats are designed to protect differently than adult seats

## Why It Is Important

- People feel so safe in their cars that they do not think about their safety equipment — and they often use it incorrectly. For example, air bags do not work properly without seat belts. Knowing how safety features are designed will help you use them properly.

## Skills You Will Use

In this chapter you will:

- describe how each safety feature of a vehicle keeps you safe
- compare older safety technologies with modern ones
- examine and test seat belt and air bag designs
- model how air bags work
- design a new safety feature or modify an existing feature to increase the safety of vehicles

## Starting Point ACTIVITY

### Safety Systems over Time

How do safety features act during normal operation and during collisions?

#### What to Do

1. Work in a team of two or three. At the top of the left page is a 2000 Buick LeSabre. On the bottom of the left page, and beside this activity, you can see a 1959 Buick LeSabre. Make a list of features in each car that might affect how safe it is to use. As you make your list, consider these questions:
   - What features help with visibility?
   - What features communicate with other drivers?
   - What features protect the occupants during a collision?
   - What features protect the car's body from minor damage during a collision?

   Try to include as many features as possible.

2. **(a)** Examine the visuals and note what feature(s) have remained the same in the design over time.
   **(b)** What features have changed over time?
   **(c)** What older safety features are no longer present?
   **(d)** What new safety features have been developed?

3. Choose five modern safety features and answer the following questions for each one.
   **(a)** How does this feature function during normal operation?
   **(b)** How does it react in a crash?

#### What Did You Find Out?

1. Present your information in a chart or series of visuals.

# 16.1 How Safety Features Work

As a safety engineer, I create new safety features and improve old ones. To check how safe a vehicle is, we build human-like dummies and see what happens to them during collisions. We crash vehicle after vehicle until the safety feature we are developing works the way we want it to. Only then does the feature get installed in cars that will be sold to the public. Engineering processes take a lot of time and money – but they save lives.

**Figure 16.1** Safety engineers such as this one make sure the vehicles you drive are safe.

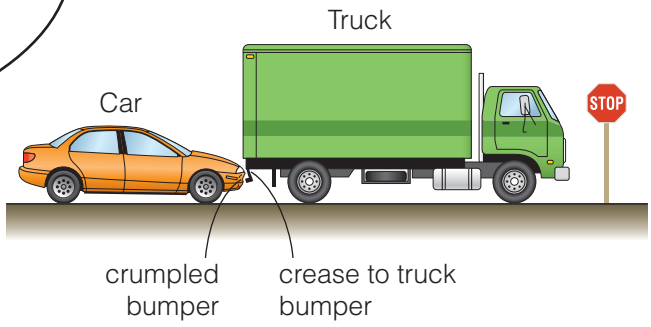



**Figure 16.2** During accidents such as this, both bumpers crumple to absorb the force of the impact. This slows the force of the collision. Often, nobody is injured in such an accident but the bumpers need to be replaced.

Chapter 15 discusses the conservation of momentum. As explained in that chapter, when one object hits another, the momentum of the faster, heavier object is transferred to the slower, lighter object.

The occupants of vehicles experience various forces as their velocities change and momentum is transferred during a collision. The safety features on vehicles work to reduce the force of a crash. In Conduct an Investigation 15–A: Collision Damage, on page 279, you learned that the force resulting from a collision is smaller if the change in momentum occurs over a longer period of time. This is the basic idea behind most vehicle safety features.

Safety features serve to slow down the collision. As a result, the occupants of the car experience less force and, therefore, receive fewer injuries.

Engineers use **crash test dummies** to determine what will happen to people during a collision. These are dolls that are as much like real human beings as modern technology can make them.

Engineers use these dummies to help them determine how well the **crumple zones** in cars work. Crumple zones are parts of the car that are made of crushable metal or fibreglass. These usually include the hood, doors, and trunk. These sections crumple when the vehicle is hit. The crumple zones slow down the collision felt by the occupants and increase the time of the collision between the occupants and the interior of the vehicle, thus reducing the force experienced by the occupants. This reduces the damage experienced by the occupants of the vehicle.

**DidYouKnow?**

An unrestrained child in a high-speed collision will have about the same momentum as a cannonball.

**READING Check**

How does safety equipment work to make collisions safer? Give one example. Use a diagram to explain how it works.

## Types of Safety Features

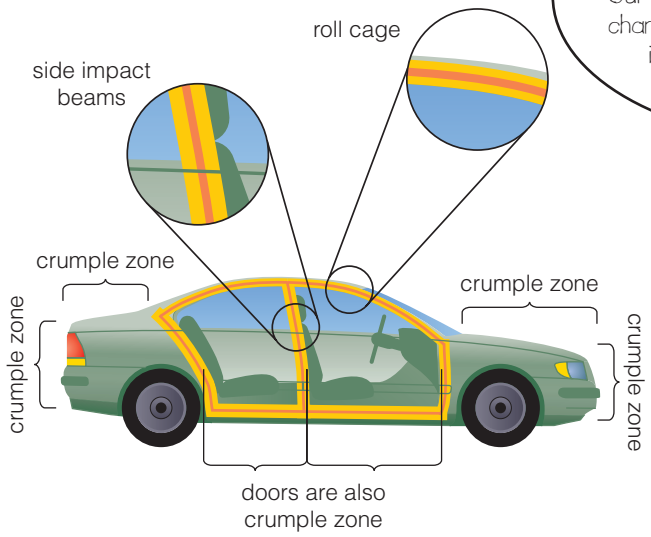



**Figure 16.3** The rigid structure of the body of the car protects passengers. Notice how the rigid structure is protected by the various crumple zones.

Have you heard that it is better to be thrown clear of your vehicle during an accident? Don't believe it. Our research and tests show that your chances of survival and avoiding serious injury are much better if you are properly held in a safe position.

**Figure 16.4** Safety engineers use tests to find out what kind of damage is done during accidents. Some of their findings may be surprising.

Crumple zones work on the outside of your vehicle. What else keeps you safe? As you probably noticed during the Starting Point activity, there are many different features. These include restraining features, operational features, and structural features.

- **Restraining features** hold occupants in one place. They prevent them from hitting the dashboard, windshield, sides, or roof of the car. They also prevent someone from being thrown out of the vehicle. Restraining features include seat belts, air bags, headrests, and child seats.
- **Operational features** operate all the time to keep you safe while driving. For example, headlights allow the driver to see clearly and warn other drivers of a vehicle's approach. Rear- and side-view mirrors assist the driver in seeing all parts of the road. Tail and signal lights warn other drivers of changes in speed and direction. Brakes allow the vehicle to slow safely.
- There are two types of **structural features**: rigid features and crumple zones.
  - Rigid features include the heavy frame, a roll cage, and side-impact beams in the doors. Each of these is built from materials that will not crumple or break under extreme pressure. In this way, they are designed to protect the people inside from anything that may hit the car.
  - The crumple zones include the hood, trunk, and fenders. These may be completely crushed in a bad accident. If the rigid frame stays intact, however, the cabin of the vehicle will keep the occupants safe.

**Try This!**

Review your list of safety features from the Starting Point activity. Classify the features you listed as restraining, operational, or structural.

**READING Check**

What is the purpose of each type of safety feature? Give an example of each type.

READING Check

Why are aluminum and plastics used frequently in the bodies of vehicles?

## Safety Features at Work

How do safety features work in actual vehicles? Study Figures 16.5 to 16.8 and read the captions. Identify the type of feature being discussed and how it works.

**Figure 16.5** 1967 Dodge Dart

I loved the sleek lines of my father's '67 Dodge Dart. Those heavy old cars had a lot of momentum when they got going! Unfortunately, in a collision, the heavy metal body of cars like this one did not absorb any of the impact. Whiplash was the least of the worries of the people inside. Many were seriously injured when they hit the hard dashboard or the rigid steering wheel.

**Figure 16.7** Identify the crumple zones on this vehicle.

Have you seen the results of our latest tests? The vehicles that crumpled absorbed a lot of force during a collision. That means less damage was done to our crash test dummies.

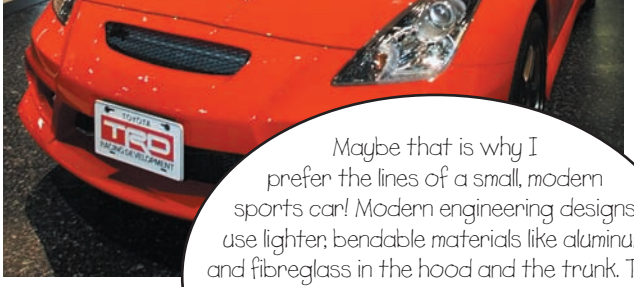
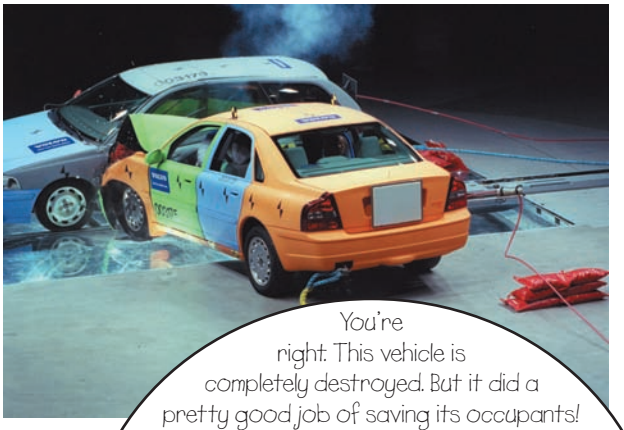


**Figure 16.6**

Maybe that is why I prefer the lines of a small, modern sports car! Modern engineering designs use lighter, bendable materials like aluminum and fibreglass in the hood and the trunk. The hood and trunk look as good as the body on those old Darts, but the ones on the new cars crumple in a collision. That's hard on the car, but protects the people inside.

**Figure 16.8** Modern cars absorb much of the force of an impact by crushing. This reduces the force of a collision and protects the occupants.



You're right. This vehicle is completely destroyed. But it did a pretty good job of saving its occupants! The outer panels crumpled, but they protected the cabin of the vehicle. That is what I have been working on for the past 10 or so years. We built and tested better roll cages. By making them of rigid materials, we formed a protective cage around the occupants. Later, we added side-impact beams to protect occupants from collisions from the side. Then we added a beam through the dash so the steering column and engine could not crush their way into the cabin.

**Figure 16.9** Imagine the amount of force behind a truck hitting a concrete barrier such as this one.

**Figure 16.10** Now picture a similar accident — only this time, the truck hits a barrier like the one shown here. How might a crash cushion protect a vehicle and its occupants?

## Road Safety Features

Vehicles are not the only things with safety features. Many roads also have **road safety features** that reduce the force of a collision by slowing the impulse.

One such technology is the crash barrier or **crash cushion**. Barrels filled with water (or sand) crush or burst on impact. This applies a slowing force to the vehicle without doing as much damage as a solid barrier.

Today's metal **guardrails** will bend (but not break) to lower the momentum of a vehicle and absorb the force of collision. In this way, guardrails prevent the vehicle from rolling over or rebounding into traffic. Some guardrails are designed so the entire section will snap off its posts if a vehicle hits any section of the railing head on. This serves to slow the vehicle safely by applying a consistent medium-strength force.

Light poles used to be immovable. Today's light poles are designed with shear pins that snap off under the force of collision. The vehicle hits the light post, but is not immediately stopped. This reduces the force of impact.

**READING Check**

Describe how one feature of the road is designed to lower the force of collision.

**Internet CONNECT**

www.mcgrawhill.ca/links/science.connect2

One new type of guardrail is designed to absorb the energy of the car and bring it to a slow, controlled stop. To see a video clip of a car running into this new type of guardrail, go to the above web site, then to Internet Connects, Unit D, Chapter 16, and then to Guardrails.

## Check Your Understanding

1. Why are cars with crumple zones better than cars that do not crumple?
2. What parts of modern vehicles are meant to be rigid? Why?
3. Describe how two road features were redesigned to reduce the force of impact.
4. Why is it important to regularly maintain the safety features of any vehicle? Mention two safety features that should be checked regularly, and explain why this is important.

**Key Terms**

crash test dummies
crumple zones
restraining features
operational features
structural features
road safety features
crash cushion
guardrails

# 16.2 Seat Belts

READING Check

Explain the difference between how a lap belt and a shoulder harness work. Which one provides better protection?

A lot of work has been done to develop a seat belt that is safe *and* comfortable. Modern seat belts are designed to stop your body from being thrown forward during a collision. The original designs were **2-point belts** or **lap belts**. These held a person across the pelvis. Unfortunately, that did not stop the upper body from moving.

The modern **3-point belt** or **shoulder harness** was designed to help restrain the upper body. Now that the entire body is restrained, it is only the head you have to worry about.

So far, safety engineers have not developed a way to restrain a person's head during a collision. That is why it is important to use a raised headrest along with the seat belt. The importance of properly adjusted headrests and what happens if you do not use them was discussed in Chapter 13.

Use the Find Out activity below to learn more about how seat belts have improved.

Find Out ACTIVITY

## Seat Belts Then and Now

How has the structure of seat belts changed since seat belts were first developed?

SKILL CHECK

- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

### What to Do

1. Compare the different features in the seat belts in Figures A and B, and the one in Figure 16.13 on page 293.
2. The figures are shown chronologically. Examine the figures and consider what design changes have occurred.
3. Hypothesize about what occurrences might have made manufacturers change designs.

### What Did You Find Out?

1. Do the analysis provided by your teacher.

**A.** 2-point belt

**B.** 3-point belt

## How Seat Belts Work

Have you ever been hit by something that flew off the back window ledge or seat when a car stopped fast? Then you have some idea about what could happen if you were not wearing your seat belt during a collision. Your body would continue travelling at the same velocity the car was going before the collision.

Modern seat belts have been carefully engineered to make sure they are there, and working, when you need them. Consider the technology that goes into making them safe.

Webbing — Seat belt material is made up of thousands of thin strands of polyester or nylon. The arrangement of these fibres allows the belt to stretch from 10 to 15 percent of its normal length during a collision. This stretching allows the passenger to stop more gradually and feel a smaller force.

Retractor unit — Inside the retractor portion of the seat belt is a clever system that involves a pendulum and a ratchet. The ratchet maintains tension in the webbing. This is why the belt is always snug on your body. By pulling gently on the webbing, you can reel out more of the belt. However, if the vehicle experiences a sudden stop, the pendulum in the ratchet mechanism swings forward. This locks a bar in place that prevents more webbing from coming out.

READING Check

Why would we want a seat belt to stretch a small amount in a collision?

### DidYouKnow?

By 1984, seven of Canada's 10 provinces, including Alberta, required occupants of vehicles to use a seat belt. The use of seat belts in Alberta climbed from about 15 percent in 1980 to close to 90 percent in 1990 after the introduction of the seat belt law.

**Figure 16.11** What regular maintenance would this part of the seat belt likely need?

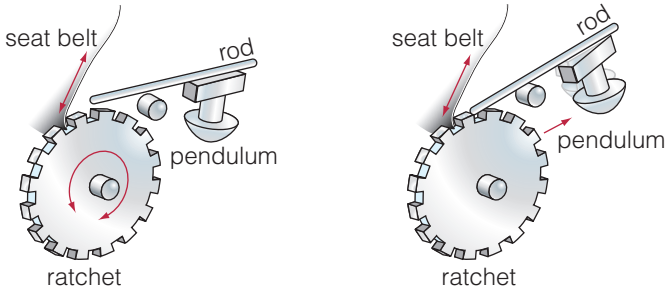



**Figure 16.12** In most seat belt systems, the belt webbing is attached to a retractor mechanism that uses a spring and spool to keep the webbing snug. A second mechanism comes into play in an accident. The ratchet and pendulum system shown here causes the seat belt spool to lock when the car decelerates quickly. How does this technology keep you comfortable and also safe?

**Figure 16.13** Some manufacturers are beginning to use racing-style or 4-point belts. These belts restrain both shoulders and distribute the force over more of the chest. This reduces stress on the ribs, heart, and lungs.

CONDUCT AN

INVESTIGATION 16-A

SKILL CHECK

- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

# Seat Belt Study

You rarely hear of seat belts breaking or not working in a collision. Yet their design is simple. Take some time to examine this system and ask yourself — could it really be any better if it were more complex?

## Problem

How are the components of a seat belt designed to produce the most important safety feature of your vehicle?

## Prediction

Do you think you will be able to stretch the seat belt webbing?

### Safety Precautions

- Take care when stretching the belt. This will require a great deal of force, and depending on how you accomplish this, there may be a potential for injury.
- Handle the weights with care. Make sure that the area below the weights is clear of objects.
- You may be working with tools or weights to complete this activity. Watch your fingers and toes!
- Clean up the work area and wash your hands thoroughly at the end of the investigation.

### Apparatus

seat belt samples including webbing, retractor system, and buckle
metre stick
stackable weights from gym
vice grips
marking pen
magnifying glass
small, thin mirror (optional)
flashlight (optional)

## Procedure

### Part 1: The Webbing

1. Explain the purpose of a seat belt. How does the belt work to reduce the force during a collision?
2. Now examine the seat belt webbing. Use the magnifying glass to see how the nylon fibres are arranged. Sketch this in your notebook. How do you think the fibre arrangement helps the function of the seat belt in a collision?
3. Mark off a certain length of the webbing (perhaps 0.5 metres).
4. Still holding the webbing in line with the metre stick, attempt to stretch the material over a desk.
5. Try various ways to stretch the seat belt webbing.
   - Place the webbing so it hangs over both sides of your desk. Loop both ends through various sizes of heavy weights. Record the mass used and how much you increased the length of the webbing.
   - Hang the webbing from the edge of a door and attach a series of heavy weights. Record the mass used and how much you increased the length of the webbing.
   - Using vice grips, try pulling on the webbing to stretch it. Be careful of your back, and have someone behind you ready to catch you in case the grip releases unexpectedly. Record how much you can stretch the webbing.

Whether they're used to restrain dogs or people, seat belts save lives. Drivers have been killed by unrestrained pets hitting them with great force during a collision. Why don't seat belts break?

### Part 2: The Retractor Unit

1. Examine the retractor unit of the seat belt.
2. Remove the plastic cover and identify the ratchet, pendulum, and bar inside.
3. Draw a diagram showing the retractor unit you examined.
4. With the cover removed, try to simulate a crash by having someone tug at the webbing while the ratchet system is moved and shaken. Repeat several times, and try several methods. What do you notice? Record your observations.

### Part 3: The Buckle System

1. Examine the buckle system of the seat belt.
   - **(a)** Is there any way to take it apart? If there is, do so.
   - **(b)** If taking the buckle system apart is impossible, suggest why.
   - **(c)** Draw a diagram of how the buckle operates.
2. Using a magnifying glass, search the release button for cracks or chips. Try using a tiny mirror and a flashlight to see into the buckle assembly.

## Analyze

1. **(a)** Were you able to stretch the belt? If so, how?
   **(b)** What does this suggest about the force experienced in a collision? Explain.
2. Describe the best method of making the ratchet system lock in place.
3. How easy is it to take apart the buckle system? What does this suggest to you?

## Conclude and Apply

4. Seat belts are supposed to be replaced after a major collision. Give possible reasons for this.

## Proper Use of 3-Point Seat Belts

Did you know that there are many ways to *wrongly* use a seat belt? In the event of a collision, seat belt misuse can be disastrous. Here are some points to remember:

- When you put the seat belt on, look at where the straps cross your body. The two strongest parts of your body are the pelvis and upper chest. This is where the belt should cross.
- Keep the belt snug. Otherwise, your body will be thrown against it. A hard stop against the narrow strap is like being hit by a flying brick.
- Make sure the diagonal portion is across your upper body. Otherwise, you have a 2-point lap belt, with all its problems.

**READING Check**

Describe two incorrect ways you have seen seat belts worn, and explain why these are unwise methods of wearing a seat belt.

**Off the Wall**

Even in collisions within the speed limit, you can expect to experience a force of six times your body weight. If you were to try to brace against the dashboard for such an impact, your arms would be trying to hold back six times your own weight!

**Figure 16.14** There are many ways to adjust a seat belt incorrectly, but only one right way to wear one.

INVESTIGATION 16–B

SKILL CHECK
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

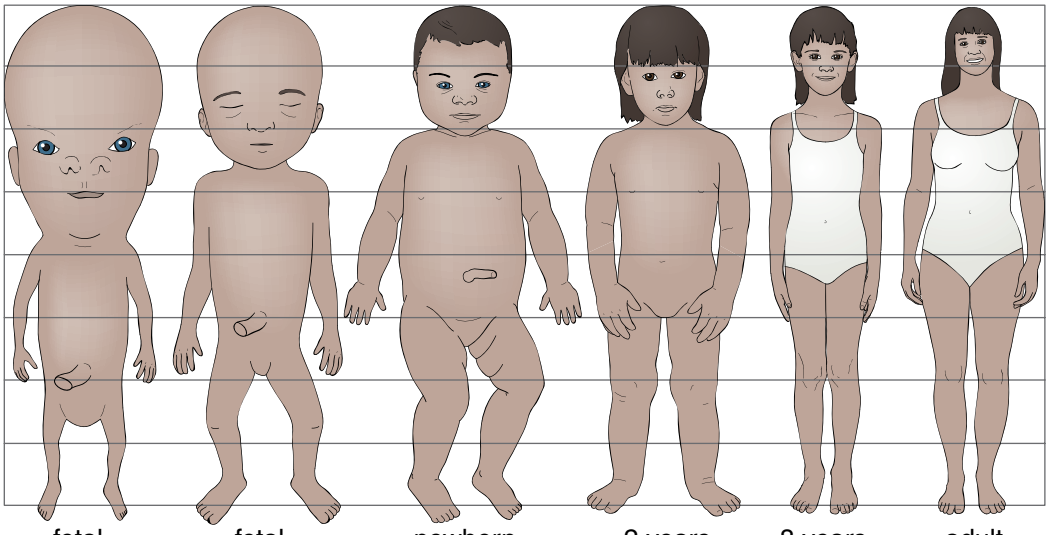
# Little Problems, Big Solutions

## Think About It

When babies are born, they move from a liquid environment (the womb) to the outside world. Their bones do not have the strength of adult bones. As you can see from the diagram below, babies and young children also have much larger heads, by proportion, than adults. That is why babies and small children need safety seats too.

## What to Do

1. Measure the length of the head compared to the length of the entire body for each of the people in the figure. Use fractions to record what you find. For example, the head size is 1/3 of the body size.




Notice what happens to your body proportions as you age. What fraction of a newborn's body consists of the head? What fraction of an adult person's body consists of the head?

## Analyze

1. Describe the trend in head size to body size as a person gets older.
2. Why would the size of a baby's head compared to its body increase the danger of injury during a collision? Use your knowledge of momentum and the differences between babies and adults to explain.
3. How are infant and child seats designed to take a child's growth into account?
4. **(a)** Why is it safer for the fetus to be suspended in fluid inside a mother's body?

   **(b)** Could this fact be used in safety technology? Explain.
5. Many child seats are designed to be placed so the child is facing backward in the vehicle. Why do you think this is so?

## Child Restraints

The Canadian Automobile Association reports that up to one third of Canadian children are not properly restrained while in a motor vehicle. This leads to as many as 10 000 injuries per year.

Children have weaker bones and muscles along with their comparatively heavy heads. Devices for children are designed to provide the extra protection this type of body needs.

Types of child seats differ based on the mass of the child. The back seat of the car is recommended for children because there is no dashboard to hit and no chance of injury from an air bag. Read the captions in Figures 16.17 to 16.20 to learn about the different kinds of children's seat and when they are used.

**READING Check**

List two reasons why children need different restraining devices than adults.

**Figure 16.15 Infant-only seats** are for children who cannot sit up by themselves yet. These are designed to face the back of the vehicle. The force of a crash would be absorbed by the entire back of the child.

**Figure 16.16** Children who weigh more than 9 kg usually have bones and muscles strong enough for a **child seat**. In this kind of seat, the child faces forward. It is still best to have such seats in the back seat.

**Figure 16.17 Convertible child seats** are used with children from birth to a mass of 18 kg. They can be used with infants and children.

**Figure 16.18 Booster seats** are made for older children who are not yet tall enough to use the seat belt properly without being in a raised position.

## Check Your Understanding

1. What advantages does a 3-point belt have over a lap belt in a collision?
2. Why does the pendulum in a seat belt swing forward when the vehicle stops suddenly?
3. Describe briefly how a seat belt should be worn. Sketch a diagram and list three important points.
4. **(a)** Why shouldn't a baby be carried in a passenger's lap? Describe some of the things that could happen in a collision.

   **(b)** Draw a diagram as part of your explanation. Use your knowledge of momentum to explain what could happen.
5. What led to the development of the 4-point seat belt? How might crash test dummies have been involved in this process?

**Key Terms**

- 2-point belts
- lap belts
- 3-point belt
- shoulder harness
- infant-only seats
- child seat
- convertible child seats
- booster seats

# 16.3 The Evolving Air Bag

**Figure 16.23** The Material Safety Data Sheets list sodium azide as extremely explosive. That is why you must make sure air bags are maintained regularly.

**Figure 16.19** When inflated, air bags fill the front part of a vehicle. The air inside cushions the occupants and slows their velocity and momentum.

**Figure 16.20** The systems in Figure 16.21 and this photo both use air to reduce momentum.

**DidYouKnow?**

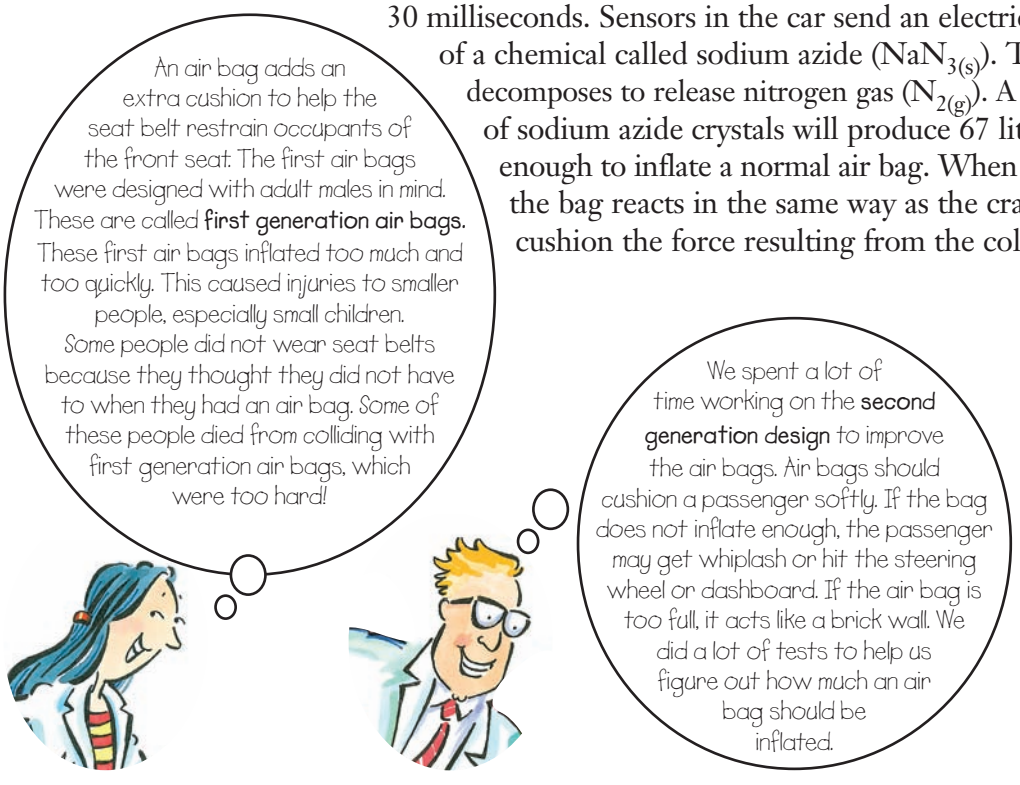
First generation air bags deployed so fast that they hit the driver at over 300 km/h!

**READING Check**

How do air bags work? How has the design improved?

An **air bag** is rolled up inside the steering wheel and the passenger-side dashboard. When activated, it performs much the same function as a parachute. Parachutes protect skydivers by safely lowering the velocity and momentum of their fall. Similarly, air bags safely slow the velocity and momentum of the occupant of a car.

In a collision, a chemical reaction inside the air bag causes it to inflate in 30 milliseconds. Sensors in the car send an electric signal to ignite a canister of a chemical called sodium azide ($NaN_{3(s)}$). The chemical quickly decomposes to release nitrogen gas ($N_{2(g)}$). A small amount (130 grams) of sodium azide crystals will produce 67 litres of nitrogen gas — enough to inflate a normal air bag. When a car occupant hits the bag, the bag reacts in the same way as the crash cushions on page 291 to cushion the force resulting from the collision.


An air bag adds an extra cushion to help the seat belt restrain occupants of the front seat. The first air bags were designed with adult males in mind. These are called first generation air bags. These first air bags inflated too much and too quickly. This caused injuries to smaller people, especially small children. Some people did not wear seat belts because they thought they did not have to when they had an air bag. Some of these people died from colliding with first generation air bags, which were too hard!
We spent a lot of time working on the second generation design to improve the air bags. Air bags should cushion a passenger softly. If the bag does not inflate enough, the passenger may get whiplash or hit the steering wheel or dashboard. If the air bag is too full, it acts like a brick wall. We did a lot of tests to help us figure out how much an air bag should be inflated.

**DidYouKnow?**

Do not place small children in the front passenger seat of a vehicle when the air bag is activated. Small children have been killed as a result of the force of collision with the air bag during even minor crashes.

INVESTIGATION 16–C

SKILL CHECK
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

# This Is You . . . This Is You in a Crash

## Think About It

In this investigation, try to imitate the proper inflation of an air bag using a balloon and an egg. Experiment to decide how full an air bag should be.

### Safety Precautions

- If you have egg allergies, please notify the teacher.
- Clean up the work area and wash your hands thoroughly at the end of the activity.

### Materials

1 or 2 eggs
cardboard milk container with top removed (2 L)
3 small balloons (large enough to fit in the milk cartons)
1 or 2 small plastic bags
garbage bag

## What to Do

1. Inflate three identical balloons to three different volumes.
   - One should be filled so it is squishy.
   - One should be filled until you can hardly press on it.
   - One should be filled so it is firm, but not hard.

   Make sure each balloon will fit into a milk carton.
2. Insert a balloon into each milk carton.
3. Place the egg in a small plastic bag.
4. Spread out the garbage bag on the floor to catch any mess that may be created during the next part of this activity.
5. Drop an egg from waist height into each milk carton. Have someone ready to catch the egg if it bounces out.
6. Record what happened to the egg in each case. Did it break? Did it bounce back? If so, how high?
7. Starting with the overfilled balloon (then the normal one, then the underfilled one), throw an egg downward into the balloon as hard as you can. Record your observations.

## Analyze

1. Which part of the procedure best simulates what happens to a person in a serious collision? Explain.
2. Which inflation seemed to give the best results with a thrown egg?
3. Did the egg break during any of the tests? Discuss what happened and what that might mean for air bag design.
4. Explain why it is necessary to still use a seat belt, even if your vehicle is equipped with an air bag. Use evidence from this activity to justify your answer.

DESIGN & DO

INVESTIGATION 16–D

SKILL CHECK
- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

# Future Safety Technology

Without a seat belt, a flying driver or passenger can apply enough pressure to knock the windshield out. An air bag could pop on broken glass or be pushed into a strange shape by a broken windshield, and then not work properly.

Apply what you know about the laws of motion by acting as a safety engineer.

## Challenge

Design a new technology that will help prevent collisions, or soften the impact to protect vehicle occupants if a collision does happen.

### Materials

The materials you use will vary, depending on how you decide to build your model.

## Design Criteria

**A.** Your new technology might be something completely new, or an improvement to a current safety feature.

**B.** It can be a feature of the car or a feature of the road.

**C.** Your design must be possible at the present time and use materials that are readily available to road builders or car makers.

**D.** You may work in a group of one, two, or three. If you have a very large project idea and can show your teacher how each group member will have a part to play, you may work in a larger group.

**E.** Create diagrams or a model of your vehicle or road feature.

## Plan and Construct

1. Begin by brainstorming ideas. Be creative, and accept all ideas for the first list.
2. Decide which ideas have the potential for a complete project.
3. Create a model or drawing of the design, and label it. Be sure you can explain or demonstrate how your safety system:
   - is stored or used during normal vehicle operation (or road use)
   - functions during a collision
   - uses the laws of physics that you learned in this unit
4. Present your new safety feature to the class. Describe how this technology works.

## Evaluate

1. How does your safety feature respond and deal with laws of motion to protect vehicle occupants? Use a diagram to show how your feature would counteract the Law of Conservation of Momentum for occupants of the vehicle.
2. Of all the technologies developed by other groups, which safety feature do you think could save the most lives?
3. Of all the technologies developed by other groups, which safety feature do you think would have the best chance of actually being used in real life, either in new vehicles or as a part of new roads?
4. How do you feel about your own part in the project? Did you do as much as the other members of your group and class? Could you have done better? Explain.

## Safety Systems Continue to Improve

Safety engineers continue to improve the safety features of vehicles. The first generation air bags caused many problems. After trials, testing, and improvement, the second generation design worked better. Second generation air bags deploy at a safer speed, at a safer force (from 20 to 35 percent less than the first generation ones), and work with the seat belt to protect car occupants.

Newer, or **third generation air bags**, are even better than the ones that came before. There are now seat sensors that detect the mass of the occupant and adjust the force of the air bag accordingly. Some of the new air bags also have switches so they can be turned off if there is a child in the front seat.

Modern seats are now designed to act like a baseball catcher's mitt. They change shape to cradle a body that is thrown against them.

- Belts and air bags should catch you gently but firmly as you fly forward.
- Seats and raised headrests should catch you gently but firmly as you fly back.

If the safety design features are all working and adjusted correctly, it is possible to come through a serious crash practically without injury!

**DidYouKnow?**

Statistics show that air bags have saved about 30 times the number of people who have been killed by them. Most of the people injured or killed by air bags were not wearing seat belts.

**Off the Wall**

A new type of air bag is being tested for use in airplanes. This bag would inflate and protect you from hitting the seat in front of you in the event of a crash or rough landing.

**READING Check**

How are modern air bags safer than the original ones?

**Try This!**

Step on an empty tin can, an empty aluminum can, and an empty paper cup. Compare how easily each crushes. Aluminum holds itself well enough to be a useful material for vehicles, but crushes safely in a collision. What about the other two materials?

**DidYouKnow?**

Crumple zones occur in the interior of modern cars as well. The steering wheels and dashboards of newer cars are soft and pliable to reduce the force of impact.

## Check Your Understanding

1. What can an air bag do that a seat belt cannot do?
2. List several reasons why you should not depend on the air bag alone.
3. How can air bags injure children?
4. Why was it necessary to reduce the force of the first generation air bags?
5. What led to the development of the third generation air bags? How might crash test dummies have been involved in this process?

**Key Terms**

- air bag
- first generation air bags
- second generation design
- third generation air bags

CHAPTER

# 16 Review

## Key Terms

crash test dummies
crumple zones
restraining features
operational features
structural features
road safety features
crash cushion
guardrails
2-point seat belts
lap belts
3-point seat belt
shoulder harness
infant-only seats
child seat
convertible child seats
booster seats
air bag
first generation air bags
second generation design
third generation air bags

## Reviewing Key Terms

If you need to review, the section numbers show where these terms were introduced.

**1.** In your notebook, write the key terms that match the following clues:

**(a)** a safety system that is in both the front and the back of a vehicle (16.1)

**(b)** part of the car that easily caves in during a crash (16.1)

**(c)** a safety system for use with children over 9 kg (16.2)

**(d)** the safest seat belt yet designed (16.2)

**(e)** can be filled with water or sand to slow a vehicle (16.1)

**(f)** a device that makes it possible for a child to use an adult seat belt (16.2)

**(g)** a safety system for use with children who are too small to face forward (16.2)

**(h)** item designed to mimic a human in mass and movement (16.1)

**(i)** technology that helps the seat belt to keep the occupant from hitting the dashboard or windshield (16.3)

**(j)** technology that adjusts itself based on the mass of the person in the seat (16.3)

**(k)** technology that replaced the lap belt and restrains the shoulder and chest (16.2)

## Understanding Key Ideas

Section numbers are provided if you need to review.

**2.** Why is the lap belt too dangerous for front seat occupants? (16.2)

**3. (a)** Draw how a seat belt should be worn and include labels that explain why. (16.2)

**(b)** List two important rules of seat belt use. (16.2)

**4.** How do the technologies listed in this chapter use the principles of impulse and momentum? (16.1, 16.2, 16.3)

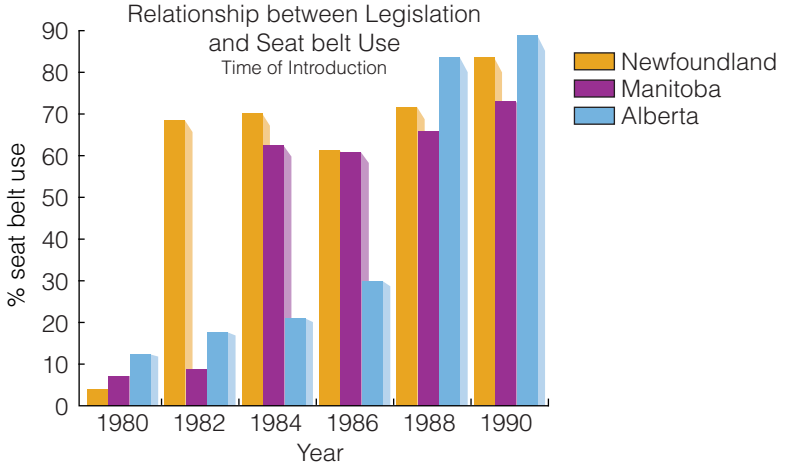
**5.** Why are seat belts attached to the frame of the vehicle instead of the seat? (16.2)

**6.** Can you use your arms to restrain yourself in a crash? Explain why or why not. (16.2)

## Developing Skills

When doing questions 7 and 8, remember that Alberta's seat belt law was passed in 1984.

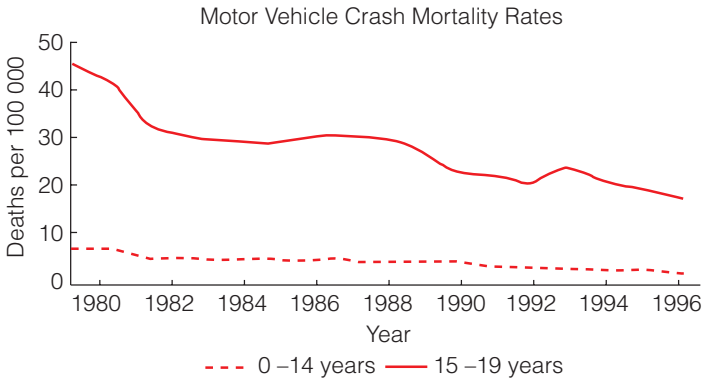
**7.** Use this graph on seat belt use to answer this question. (16.2)



**(a)** What is being described here? Use your own words.

**(b)** Using the graph, suggest which year seat belt laws were introduced. Explain your answer.

**8.** Use this graph on road fatalities to answer questions (a) to (e). (16.1, 16.2, 16.3)




**(a)** What does this graph report?

**(b)** From 1980 to 1990, what was the overall change in the number of fatalities for 15–19 year olds?

**(c)** What was the change in the number of fatalities for the 0–14 age group between 1980 and 1990?

**(d)** What was the change between 1990 and 1996 in the 0–14 age group?

**(e)** What technology might have helped the number of fatalities to drop between 1990 and 1996? Explain.

## Problem Solving/Applying

**9.** How would you redesign the seat belt (or any part of it) to be safer than it is today? (16.2)

**10.** Why do you think there are no air bags in back seats? (16.3)

**11.** If an air bag deploys with force enough to hold back an occupant of 80 kg, what might happen to an occupant of 40 kg? Explain. (16.3)

**12.** What could be done to increase the frequency of seat belt use by Canadians? (16.2)

**13.** Windshields are designed not to shatter inward. They are glued on so if something from the inside of the car hits them, they pop out. How does windshield design help reduce the force acting on a passenger in a collision? (16.1)

## Critical Thinking

**14.** Why do you think lap belts instead of shoulder belts were used in the rear seats of many vehicles? (16.2)

**15.** The width of seat belt webbing is usually about 50 mm. Using what you know about force, describe why wider webbing is safer than narrow webbing. (16.2)

**Disc CONNECT**

To review what you have learned about momentum, load the student CD-ROM onto your computer and launch the **Crash Test** applet.

**Pause & Reflect**

1. If the future holds new forms of rapid transit (high-speed trains and supersonic aircraft), what new safety technologies may have to be developed to deal with these new velocities and new dangers? Think about protecting occupants and about preventing and decreasing the force of collisions.
2. Many people think the 4-point seat belt will be safer than the 3-point version. The same is true of third generation air bags and other technologies. What problems or issues might prevent the implementation of these newer technologies in future cars?

unit D PROJECT

SKILL CHECK

- Initiating and Planning
- Performing and Recording
- Analyzing and Interpreting
- Communication and Teamwork

# Better Dummies, Safer Vehicles

You have already had a try at designing safer safety equipment. In this project, you will try to design the best crash test dummy you can with the materials available to you. As you do, consider what you can do to make the dummy as human-like as possible.

## Challenge

During this project, you will:

1. Construct a realistic dummy.
2. Use the dummy during various crash tests.
3. Analyze the dummies developed by you and other members of the class, and assess how human-like each dummy is.

### Safety Precautions

- As you plan each part of your procedure, consider the precautions you must take to prevent injury to classmates or school property.
- Clean up the work area and wash your hands thoroughly at the end of each work period.

### Materials

video camera
TV and VCR
crash car (either a child's car or something rigged up using a caretaker's dolly)
bendable wire (for skeleton)
soft fruit (for internal organs)
modelling clay (for features)
pillowcase
straw
other materials suggested by design

## Design Criteria

**A.** As a class, design a way to use a child's car or caretaker's dolly to test all the crash test dummies made by members of your class.

**B.** Dummies can be of any design, as long as they fit in the crash car. The goal is for each dummy to simulate the injuries a real human would get in a crash.

**C.** Plan and build a crash course.

**D.** Design a crash procedure.

## Plan and Construct

### Part 1: Research

1. Before starting to plan the crash test dummy, consider what research you need to do. The following questions will help you.

   **(a)** What do you already know about the human body that will help you with this project?

   **(b)** What do you need to research about the human body?

**(c)** What do you already know about crash test dummies and crash tests that will help you with this project?

**(d)** What do you need to research about crash test dummies and crash tests?

2. Do the research you identified in Step 1.

3. **(a)** List the materials you will need to construct your crash test dummy. Are those materials available?

**(b)** What dummy features might best show the force of impact?

### Part 2: Build a Crash Test Dummy

4. Plan some form of skeleton for your dummy. The skeleton should be able to show the effects of a collision. For example, consider materials that might fracture in a similar way to bones.

5. Make a body and attach it around your skeleton. What can you do to make the body as much like a person as possible? Can you show bruising effects? Can you think of any way to simulate the skin and internal organs?

6. Make a head. How will you attach it to the body? What materials will you use for skin, eyes, and neck?

7. Make refinements to your crash test dummy to make it look as realistic as possible.

### Part 3: The Crash Test

8. All groups will use the same car and the same crash procedure.

**(a)** As a class, decide if your car should have a seat belt or any other safety equipment.

**(b)** Develop the crash procedure(s).

9. Set up a crash site.
   - There should be a long enough run to get a fast, consistent speed.
   - Make sure you build or use some kind of barrier at the end of the run. For example, you might want to pad an area with gym mats. Use enough padding to preserve the wall and the car.

10. Use a video camera on a tripod to record the crash events.

11. Make an observation chart to help you record and organize your data about each dummy.

## Evaluate

1. Use the "slow" feature on the camera or VCR to observe the crashes.

**(a)** How well did each dummy perform? **Note:** A dummy should behave like a human in every respect. A dummy that shows its injuries in the most detail is better than a dummy that does not show any injuries.

**(b)** Brainstorm ways in which the dummies could be redesigned to be more realistic.

2. **(a)** What injuries were received on each body part?

**(b)** Did the injuries show up in the same way they would in a real human?

**(c)** Rate each dummy out of 10.

3. Use your observations to decide which aspects of the homemade dummies did not do a good job of replicating a human. Explain your answer.

4. Redesign and remodel your dummy to avoid some of the problems noticed in question 3. Test the new model to see if it works better.

**Internet CONNECT**

www.mcgrawhill.ca/links/science.connect2

To help you with your research about dummies, crash tests, and the human body, go to the above web site, then to Internet Connects, Unit D Project, and then to Crash Test.